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Isolated Galaxies and Isolated Satellite Systems

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Abstract. We search for isolated galaxies using a volume-limited sample of galaxies with $0.02 < z < 0.04742$ from SDSS DR7 supplemented by bright galaxies. We devise a diagnostic tool to select isolated galaxies in different environments using the projected separation ($r_{\rm p}$) normalized by the virial radius of the nearest neighbor ($r_{\rm vir,nei}$) and the local background density. We find that the isolation condition of $r_{\rm p} > r_{\rm vir,nei}$ and $\rho < \bar{\rho}$ well segregates the CIG galaxies. We confirm the morphology conformity between the host and their satellites, which suggests importance of hydrodynamic interaction among galaxies within their virial radii in galaxy evolution.

1. Introduction

There have been many attempts to search for isolated galaxies since the Catalog of Isolated Galaxies (Karachentseva 1973, hereafter CIG). Most of the previous studies used selection criteria similar to those of Karachentseva (1973) who adopted diameters of galaxies and projected separations between a target galaxy and its neighbors. Of course, there are several attempts to constrain isolation better by adding more parameter such as apparent magnitude (eg., Allam et al. 2005) and line of sight velocity difference (eg., Marquez & Moles 1966) or by employing new criteria such as tidal strength (Varela et al. 2004).

Recent investigations of the effects of environment on the morphology of galaxies show that the morphology of a galaxy depends on the local background density as well as the morphology of the nearest neighbor (Park et al. 2007, 2008). The effects of the nearest neighbor become dominant when a target galaxy is located within the virial radius of the nearest neighbor. Since the virial radius of a galaxy is assumed to be the domain of strong tidal and hydrodynamic interactions, it can be a good parameter to select isolated galaxies.

The purpose of the present study is to devise a better operational criteria for the selection of isolated galaxies using SDSS DR7 supplemented by bright galaxies from various catalogs. We also want to demonstrate that the morphol-

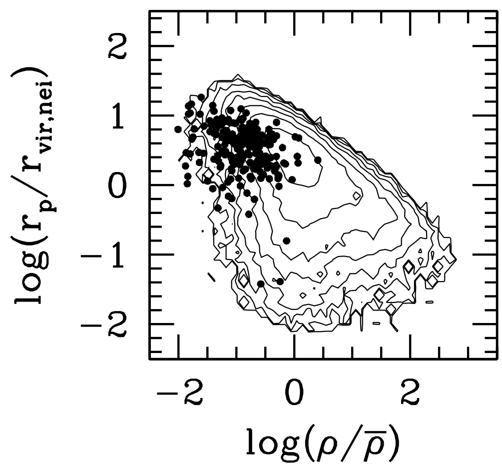

Figure 1. Distribution of galaxies in the $\log(r_{\rm p}/r_{\rm vir,nei})$ versus $\log(\rho/\bar{\rho})$ diagram. The CIG galaxies are plotted as solid circles and the distribution of the volume-limited sample of galaxies are represented by the iso-number contours.

ogy of galaxies within the virial radius of a galaxy is likely to resemble each other through the hydrodynamical interactions.

2. Virial Radius and Local Background Density

The morphology of a galaxy depends on the local background density as well as the morphology of the nearest galaxy (Park et al. 2007, 2008) but the effects of the nearest neighbor are dominated within the virial radius of the nearest neighbor (Park et al. 2008, Park & Choi 2009). We calculate the virial radius of a galaxy,

$$r_{\rm vir} = (3\gamma L/4\pi\rho_c/200)^{1/3}$$

where ρ_c is the critical density of the universe and γ is the mass–to–light ratio (Park et al. 2008). We adopted $\gamma = 2$ for early-type galaxies and $\gamma = 1$ for late-type ones. The local background density is calculated as

$$\rho = 7/4\pi r_p^2$$

where r_p is projected distance to the 7th nearest galaxy that is brighter than $M_r = -19.5$ with line–of–sight velocity difference less than 1000 km/s.

3. Isolated Galaxies

3.1. CIG Galaxies

Fig. 1 shows the distribution of the primary sample galaxies in the $\log(r_{\rm p}/r_{\rm vir,nei})$ versus $\log(\rho/\bar{\rho})$ diagram where $r_{\rm vir,nei}$ is the virial radius of the nearest neighbor galaxy and $\bar{\rho}$ is the mean local background density of the primary sample.

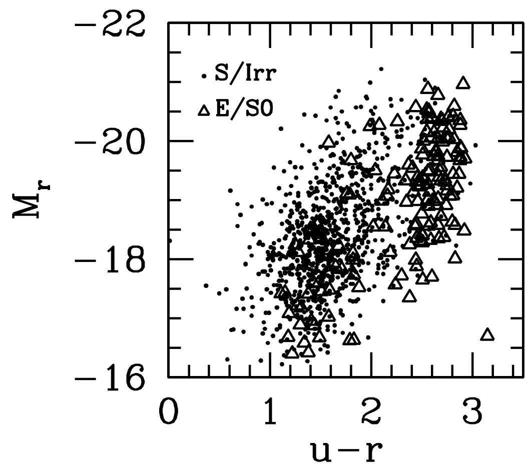

Figure 2. Luminosity and color of extremely isolated galaxies.

There is an upper limit of $\log(r_{\rm p}/r_{\rm vir,nei})$ for galaxies at a local background density which seems to be set by the anti-correlation between the neighbor distance and the local background density. The other two boundaries of the distribution are not well defined but they reflect the wide ranges of separation relative to the neighbor's size for the galaxies in low local densities and the wide ranges of local densities for galaxies with small relative separations. There are several interesting features in Fig. 1, but here we note that the lower limit of the relative separation of galaxies in the lower right part of the diagram is thought to be caused by the cannibalism prevalent in the densest regions.

As shown in Fig 1, most of CIG galaxies are located under-dense regions with $\rho < \bar{\rho}$. Only a small fraction of CIG galaxies are highly isolated galaxies with $r_{\rm p}/r_{\rm vir,nei} > 10$. Since CIG galaxies, which are thought to be a representative sample of isolated galaxies, are well segregated from others in $\log(r_{\rm p}/r_{\rm vir,nei})$ versus $\log(\rho/\bar{\rho})$ diagram, the virial radius when it is used with the local background density seems to be a good selection criterion for isolation of a galaxy.

3.2. Galaxies in Extreme Isolation

Galaxies in extreme isolation is of interest for many reasons. In Figure 2, we present a relation between the luminosity and color of galaxies that have no companion within 2 Mpc. We determined morphology of galaxies using the automated morphology classifier that is devised specifically for SDSS galaxies (Park & Choi 2005). As shown in Figure 2, late-type galaxies (small solid circle) show a smooth distribution while early types (triangles) display a bimodal distribution centered at $u-r \approx 1.5$ and $u-r \approx 2.6$, respectively for the blue and red groups. Early-type galaxies in the former group are mostly blue elliptical galaxies of which a large fraction is dwarf elliptical galaxies. Galaxies in the latter group consist mostly of normal elliptical galaxies and their distribution resembles the red sequence observed in the local universe.

3.3. Isolated Satellite Systems

A galactic satellite system consists of a central host galaxy and its satellite galaxies which are fainter than their host galaxy. We follow the method of Ann et al. (2008) to find out isolated satellite systems. We found about three times more satellite systems than Ann et al. (2008) due to an enlarged sample size. We confirmed the morphology conformity between host galaxy and its satellites found by Ann et al. (2008) in the present enlarged sample. As suggested by Ann et al. (2008), the morphology conformity in galactic satellite systems is believed to be caused mainly by the hydrodynamical interaction between hosts and satellites,

4. Discussion and Conclusions

We devised a diagnostic tool for selection of isolated galaxies using relative separation ($r_{\rm p}/r_{\rm vir,nei}$) and the local background density. We showed that CIG is a really good representative sample of isolated galaxies since almost all the CIG galaxies in common with SDSS DR7 are located in under-dense regions, with the projected distance to the nearest neighbor ($r_{\rm p}$) greater than the nearest neighbor's virial radius ($r_{\rm vir,nei}$). The success of Karachentseva's criteria seems to be due to the proper consideration of the projected separation relative to the size of the companion.

We derived a subset of isolated galaxies that have no companion galaxy within 2 Mpc, most of which is thought to be located in the extremely under-dense regions like voids. There is a bimodal distribution of early type galaxies in this region in the M_r versus $u-r$ diagram. The early type galaxies with red colors follows the red sequence and are thought to be normal elliptical galaxies while the early type galaxies with blue colors are dominated by dwarf ellipticals.

We confirm the morphology conformity in galactic satellite systems found by Ann et al. (2008). Since morphology conformity is more prevalent inside the virial radius of host galaxy, it seems to be mainly driven by hydrodynamical interactions between the hosts and satellites that lead to the transformation of their morphology.

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